REDUCED RISK MANAGEMENT

OF INSECT PESTS IN SUGARBEETS

CONTRACT NUMBER: 00-0204S

PROJECT FINAL REPORT

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EXECUTIVE SUMMARY

The beet armyworm (*Spodoptera exigua*) has been identified as the most important sugarbeet pest in recent years. This pest reduces seedling density during stand establishment and defoliates plants and feeds on the sugarbeet root, causing significant yield loss at harvest. Presently, growers manage beet armyworm larvae with foliar applications of primarily chlorpyrifos (Lorsban®) and methomyl (Lannate®), which are susceptible to FQPA regulatory actions. The overall goal of this project is to demonstrate improved integrated management of insect pests through reduced application of insecticides and preservation of beneficial insects.

Earlier demonstrations were conducted at the U.C. Davis campus and in the south San Joaquin Valley and Imperial Valley. Beginning in 2001, sugarbeet production was concentrated in the South San Joaquin Valley (Merced County to Kern County) and the Imperial Valley due to beet factory closures at Tracy and Woodland, California, in December 2000.

The objectives of the sugarbeet PMA are:

1) to demonstrate alternative, lower risk insecticides for the management of armyworms on seedling sugarbeets and to provide information to growers that would aid a decision to adopt reduced-risk options.
2) to demonstrate an improved monitoring program in combination with reduced-risk insecticides that growers can use to manage late season armyworm infestation and improve production.

Seedling protection in establishing stands in the harsh environment of the Imperial Valley is of paramount importance to growers. Grower yields are closely related to final plant stands. Traditional grower practice requires multiple insecticide treatments in establishing plant populations. These are both pre- and post-emergent. Strip trials were established to demonstrate seedling protection using grower preferred treatments and seed treated with an application of the reduced-risk systemic insecticide imidacloprid (Gaucho®). Utilization of this seed treatment protects seedlings against certain pests that must otherwise be controlled by insecticide application.

A field scale trial using traditional and biorational techniques to manage beet armyworm was established in Fresno County in each of 2000, 2001 and 1002. Two fields were utilized with about 30 acres in each field treated with biorational practices, and the standard practice was used on the remaining 60 acres of each field. The 60-acre plots were treated by traditional means (chlorpyrifos other OPs, methomyl, and Success®), and the other 30 acres were monitored using pheromone trapping techniques and sprayed with reduced risk materials when beet armyworm larvae were most susceptible. Sweep netting was incorporated to monitor secondary pest problems and effects on beneficial populations between the traditional and reduced risk material applications. An integral part of this research was to provide growers and PCA's with an easy and effective method of monitoring target pests to optimize insecticide application. Effective monitoring facilitates treatment timing in the most efficacious manner.

The sugarbeet PMA successfully demonstrated that biorational control of beet armyworm has merit when coupled with improved, effective pest monitoring techniques. Success® was achieved as well in alternative seedling protection through application of a reduced risk material as a seed treatment. This strategy also indicated the potential for reduction of insecticide applications currently made under the preferred grower practice.

In conclusion, improved integrated management of beet armyworm in sugarbeets is warranted, and usable damage thresholds and monitoring techniques must be developed to achieve this goal. In addition more effective reduced risk materials must be used to aid in the development of this IPM program. Reduced risk systemic materials, applied as a seed treatment, demonstrate clearly the benefits of this strategy in both protection of seedlings and reduction of the number of pesticide applications necessary for crop establishment. More effective reduced risk materials may expand the scope of insect control, when used as a seed treatment, further enhancing environmental benefit.

Report on 2002 Pest Management Alliance Activities:
Reduced Risk Management of Insect Pests in Sugarbeets
Priority Area 1

Objective 1: Improving Sugarbeet Stands and Reducing Pesticide Use in the Imperial Valley
Stephen Kaffka

Summary

Loss of emerging sugarbeet seedlings to insects is considered a serious problem in the Imperial Valley. Growers rely on the use of carbamate and organo-phosphate pesticides for control, but these chemicals will be restricted in the future because of environmental concerns. To quantify losses and to evaluate new plant protection methods, different ways of protecting emerging sugarbeet seedlings were compared in farm fields over three years. Treatments included:

1) the current practice using chlorpyrifos applied to soil at planting combined with up to four post-emergence sprays using chlorpyrifos/diazinon mixtures,
2) seed treatment using imidicloprid at two different rates (20 and 45 g a.i. per unit of seed), and
3) other combinations of seed treatment with a single post emergence treatment with chlorpyrifos/diazinon. All treatments were compared to a control treatment
4) with no pre- or post-emergence insecticides. Seedlings were counted weekly until 6 to eight leaves had appeared. Plant populations were determined at harvest and yields compared. Pre-emergence pesticide applications (either applied to the soil or the seed) resulted in significantly more seedlings emerging and surviving than other treatments in all three years. In the first year, approximately 80 % of the seed emerged when protected with an insecticide, while approximately 55% of unprotected treatments emerged. Seed treatment was as effective as soil treatment. In the second year, the seed treatments resulted in significantly more emergence than treatments not receiving a pre-plant insecticide, but 10 % fewer seedlings than the soil insecticide treatment. In the third year, approximately 70 % of seed resulted in established plants in insecticide treatments. In all three years, much less post-emergence loss was observed than growers expected, ranging from 3 % to 10 % of the emerged seedlings. When sound irrigation practices are used, better rates of emergence can be achieved than previously believed in the Imperial Valley, and losses can be controlled with fewer pesticides and at less cost. Smaller seeding rates are possible. Root and sugar yields were unaffected by treatments because of high seeding rates and the survival and regrowth of damaged seedlings. Other factors influencing differences among the three trials were the use of pre-irrigation and different planters.

Introduction

Sugarbeets are an important crop in the Imperial Valley. Once established, they grow well during the winter and spring months in the low desert. Planting takes place, however, during September and early October, when air and soil temperatures are above optimum, and the populations of insects preying on sugarbeet seedlings such as flea beetles (*Systena blanda*) and armyworms (*Spodoptera* sp.) are very large. Growers believe that control of insects should begin as soon as seedlings appear and continue until late autumn, otherwise stand failure is considered certain. Typically, growers expect no more than half the seed planted to result in established plants. Management based on these assumptions has been successful for many years, but the most commonly used materials for control (methomyl, chlorpyrifos, and diazinon) are carbamate or organo-phosphate type compounds which face restrictions on their use for environmental reasons. There are no well-established alternatives to the use of these materials for sugarbeet seedling protection.

There is no published assessment of rates of seedling emergence and survival for the Imperial Valley. It has been common practice in the Imperial Valley to over-plant seed and then hand thin to achieve acceptable plant populations. More recently, growers have been trying to plant to a stand, but without systematic analysis of this practice. In Great Britain, Durrant (1988) and Durrant et al. (1988), carried out systematic analyses of seedling emergence and survival which led to improvements in stand establishment practices.

The objectives of this study was to evaluate the sugarbeet emergence and seedling mortality in farmers' fields in the Imperial Valley and to investigate alternatives to conventional insect control methods that could substitute for the use of insecticides that will be restricted, particularly organo-phosphate insecticides like chlorpyrifos

Methods

To demonstrate alternative seedling protection strategies and document loss to insects and other causes, three trials were conducted in farmers' fields in the Imperial Valley in California from fall 1999 to spring 2002. Five different pre- and/or post emergence treatments were compared each year (Table 1). Treatments were replicated three times. Beta 4776R, a commonly planted variety in the area was used in all trials. All of the seed was from the same seed lot each year. Plots had 20 rows that were 75 cm wide and ran the length of the field. Post emergence pesticides were applied by helicopter or tractor in the appropriate plots. Emerging seedlings were counted in two 7.6 m long subplots in the middle three rows in each plot, four to five times from initial irrigation to the six to eight leaf stage. Counting started at 9 or 10 days after irrigation. The above-ground portions of 30 seedlings were collected from one of the middle rows of each subplot near the counted area after final counts in the fall. These were dried and weighed for comparison at the six to eight leaf stage in 1999 and 2001, but at 10 to 12 leaves in 2000, as a measure of above-ground dry matter loss to insect grazing. Dry matter weights were normalized each year to allow more direct comparison.

To keep track of emergence and mortality, each seedling was labeled with a small wooden stake at emergence. The stake was removed later if the seedling died and the cause of mortality was evaluated visually in the field. Using stakes allows for the identification of the majority of seedlings appearing. Those disappearing during the first three or four days from the start of emergence will not have been counted. The sum of the number appearing is *cumulative emergence*. The last count made at the 6 to 8 leaf stage when hand or mechanical thinning would normally be done, was considered to be the *final establishment*. The amount of seed planted was determined by weight and target planter spacing. The starting amount of seed was known and the amount of seed remaining after planting the respective plot areas and was weighed to get an exact weight for the seed planted. This was divided by the known field area to determine the seed population. We assume that planting occurred uniformly (Table 1). *Pre-emergence losses* were calculated by difference between observed cumulative emergence and seed planted. Yields were collected in two 30 m rows which included some of the previously counted plot areas. Roots were analyzed for sucrose content at the Spreckels Sugar lab in Brawley, California. In spring 2002, one plot, (a control treatment plot) was accidentally harvested prior to measurement, so that treatment is average of two rather than three reps. Single degree of freedom contrasts for the important treatment comparisons were used to determine the significance of treatment differences (Littell et al., 2002). Data were analyzed using SAS v 8.2 (SAS, 2002).

Results

Each year was different from the others, but some common patterns emerged. Flea beetles and beet armyworm were the most common insects observed. Flea beetles were observed in plots each year from initial seedling emergence onwards. Flea beetle populations were judged to be largest in fall 2001 compared to other years, but they caused significant damage to seedlings in all three years. Armyworm pressure varied, with the largest numbers observed in fall 1999, and fewer in the other two years. Armyworm eggs were not observed until several days after emergence and larvae only after 7 to 10 days from seedling emergence. Stand establishment results for all three years are summarized in Table 2. Single degree of freedom contrasts for important treatment effects are reported in Table 3.

Cumulative emergence

Seedling emergence was greatest when pre-emergence insecticides were used in all three years. In two of the three years (1999 and 2001), there was no significant difference between rows with soil-applied chlorpyrifos and seed-applied imidicloprid. In 2000, there was a difference, with imidicloprid treated seeds resulting in approximately 10 % lower emergence on average than the chlorpyrifos plots. Overall, emergence was substantially reduced in 2000 compared to the other two years. In fall 1999, emergence reached 80% of seeds planted, and in fall 2001, cumulative emergence was approximately 70 % of seed planted when an insecticide was used and 50 % without. In contrast, in 2000 the best treatment resulted in approximately 50% emergence and overall emergence results were 20 to 30 % lower for all treatments than in the other two years. Emergence was delayed slightly that year by the imidicloprid treatment as well (Fig. 1).

Pre-emergence losses are determined by difference (Table 2). Average pre-emergence losses varied over the three years. For treatments with insecticides at planting, these losses range from

20 % to 30 % in the two years when pre-irrigation was used, including non-viable seed. In 2000, without pre-irrigation, pre-emergence losses increased another 20 % across all treatments.

Post emergence losses (*cumulative mortality*). The number of seedlings lost after emergence until the 6 to 8 leaf stage, was much lower than anticipated in two of the tree years. In 1999 and 2001, values ranged from less than 1 % of the seed planted to almost 10% of the seed planted. Converted to percent losses of emerged plants, losses ranged between 1 % and 30 % but most were less than 10% of the seedlings emerged (Table 2), far less than pre-emergence losses, and smaller than generally anticipated by growers. In fall 2000, when seedlings were stressed by irrigation practice, losses were larger both relative to the number of seedlings emerging and absolutely.

Establishment at six to eight leaves. The percentage of seeds resulting in established seedlings is reported in Table 2. There were significant differences between the treatments using an insecticide and those that did not. Pre-emergence losses were the most important factor affecting the number of seedlings established in all three years.

Seedling growth. In all three years flea beetles were present in the plots and damaged seedlings from the cotyledon stage onwards. Later, armyworm larvae appeared, and began to damage seedlings. The dry weight of seedlings at thinning reflects insect damage after emergence and is compared in Fig. 2. Results varied by year, in relation to insect grazing pressure. Seedling dry weights were affected by post-emergence insect grazing in 1999 and 2001, but not in 2000. 1999 was regarded as a severe armyworm year by growers, while few were found on seedlings in 2000 and 2001. In 2001, flea beetle numbers were the largest observed during the three years. The Growers treatment, which included 2 to 4 post-emergence aerial sprays with chlorpyrifos/diazinon (C/D) mixtures, resulted in the largest seedlings in two of the three years at thinning. This effect was not present in 2000 when insect numbers were low. Higher dry weights and a lack of significant differences in fall 2000 also reflect longer crop development, when differences in post-emergence damage may have diminished.

Yields. For the most part, there were no significant differences in root yields, sugar percentage or gross sugar yields among the treatments in most years (Table 4, Fig. 3). In the first year, the growers and imidicloprid treatments resulted in small increases in gross sugar yields, while in the third year, the control treatment out yielded the grower's treatment. Even though plant populations and seedling sizes differed in early autumn, by harvest in early April the next year most yields were similar. This suggests that sugarbeet seedlings can tolerant a significant amount of insect damage.

Discussion

Differences in irrigation practice had the greatest effect on stand establishment. While comparisons of irrigation practices were not a focus of this research, all environmental factors influencing seed interact to result in successful or unsuccessful stand establishment. Because most other experimental conditions were similar in all three years, the effects of irrigation practices are apparent. The relative emergence patterns each year are compared in Fig. 1 and reveal significant delays in emergence in the second year, a result characteristic of a lack of oxygen in soils and possibly complications with salinity (Lexander, 1993). Because the field was not pre-irrigated in 2000, the initial irrigation lasted for approximately 8 days, creating saturated conditions for an extended period. There also appeared to be a negative interaction between prolonged periods of soil saturation and imidicloprid treatment. The performance of imidicloprid-treated seeds was significantly poorer in fall 2000 plots than in the other two years compared to C/D treated plots (Tables 2 and 3).

In the Imperial Valley, where pre-emergence losses appear to be large, an insecticide applied to the soil or to the seed appears necessary. The larger number of seedlings emerging and becoming established in treatments including a pre-emergence insecticide in this trial leads to the inference that insect damage is occurring to seeds and emerging seedlings before they appear above ground. Such damage has been reported in England and elsewhere in Europe, where springtails (*Collembola sp*.) are sometimes implicated in losses (Durrant, et al., 1988). Growers know about the potential for such losses but the amount of loss has not been quantified before in California to our knowledge. Early post-emergence seedling damage appeared to be due almost entirely to flea beetles. Armyworm moths must first locate seedlings and then lay eggs. Eggs take several days to develop and may be subject to predation or disease themselves. In contrast, flea beetles were present in the field at planting. Imidicloprid is very effective against flea beetles even at low rates and substituted well for soil applied chlorpyrifos and the first and possibly the second or even third aerial applications of C/D mixtures as well. The amount of insecticide used as a seed treatment was only approximately 40 to 90 grams a.i. per ha, compared to several kg ha^{-1} of C/D. This is a significant reduction in pesticide use.

During fall 2001, when post-emergence flea beetle grazing was more intense, the 20 g treatment resulted in smaller seedlings than the 45 g treatment, because it was not as persistent as the larger rate. When planting occurs early in the season, insect pressure likely will be most severe and occur for longer during the seedling stage. If a smaller imidicloprid rate is used, growers will have to scout fields to determine if additional post emergence protection is needed as the season progresses. Fields planted later in the fall, however, may need no post-emergence protection and the 20 g rate may be sufficient protection for the entire stand establishment period.

Fig. 2 shows that frequent post-emergence spraying with C/D mixtures consistently resulted in the largest seedlings at establishment compared to relying on imidicloprid alone. The imidicloprid treatments were more variable but still acceptable. A combination of imidicloprid and one post-emergence spraying led to similarly uniform results (not shown). This intermediate treatment still results in a reduction in use of the more environmentally risky C/D pesticides. Growers using imidicloprid without C/D post emergence treatments must tolerate some grazing damage to seedlings. The amount that can be tolerated has not been quantified and may be variable, but even significant post-emergence damage in these trials compared to the fully sprayed treatment did not affect gross sugar yields the following spring. To help guide growers in deciding whether to spray or not, it may be helpful to consider that yields were essentially similar for all treatments in these trials (Fig. 3).

Costs of establishment. Costs for the establishment period are reported in Table 5. The cost of seed is not included. The target planting rate was set by the grower-cooperators and was reduced each year as they realized that emergence and seedling survival were better than the commonly anticipated 50 %. In the first year, 407,500 seeds/ha were planted, in the second, 222,000, and in the third 172,800. This reduced both the costs of seed and of chemicals like imidicloprid applied directly to the seed, saving the growers a significant amount of money. Other costs declined as well. In 1999, there were more post-emergence sprays applied than in the other two years. This was due in part to variable insect pressure but also to increasing grower confidence in the survival of partially damaged seedlings. A decline in profit margins is a long-term trend in agriculture that will only continue. As profit margins decline, improving stand establishment practices offer the opportunity to save money as well as spare the environment.

There are limitations to these trials that may have influenced results. The first is that drift from sprayed areas next to the plots, as well as control of insect populations in adjacent areas of the field may have reduced insect numbers within the plots. Plots were large in size. Twenty rows equal approximately 12.7 m and there were 4 unsprayed plots in every set of five. Nonetheless, the effects of drift and the possibility of reduced post emergence insect pressure within plots cannot be excluded. This difficulty is unavoidable in all experiments of this kind. If experimental plots were partially protected from damage, then post-emergence losses observed in these trials are underestimates of the amount of loss possible and may underestimate the need for post-emergence insect control. Plot size had no influence on pre-emergence losses, however, because there was no drift to consider at planting.

Secondly, the years during which these trials were conducted and the locations may not have been representative of the severity of insect pressure possible in the Imperial Valley. But in response to this concern, differences in insect pressure were observed in all three years, though not quantified. And three different fields resulted in reasonably consistent results in all three trials, even though yearly influences and irrigation practices varied in important ways. Lastly, the lower rate of imidicloprid, 20 g a.i. per 100,000 seeds, was evaluated only the last two years, but relative seedling emergence results were similar in both years (Tables 2 and 3) .

Conclusions

1. Pre-emergence pesticide applications resulted in significantly larger numbers of seedlings than the treatments without them.

2. Imidicloprid applied to seeds was a satisfactory method of controlling per-emergence seedling losses and resulted in adequate numbers of sugarbeet seedlings for a successful commercial crop. Flea beetles were the principal cause of damage at emergence and were well controlled by imidicloprid at the 45 g a.i. per unit of seed rate. The lower rate of imidicloprid (20 g a.i. per unit) resulted in similar numbers of seedlings compared to the growers treatment and the other higher rate treatments, but apparently did not reduce post emergence flea beetle damage to seedlings as well as the larger rate. If the lower rate of imidicloprid is used, there will need to be field scouting for flea beetle and armyworm damage after emergence, and a decision made whether additional control measures are needed.

3. Establishing a large percentage of seeds as seedlings saves growers money on seed costs. Using a seed treatment insecticide reduces the amount of pesticides applied, with imputed environmental benefits.

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Table 1. Trial descriptions

Year	1999	2000	2001
Field size (ha)	80	80	45
Seed rate (per ha)	407,500	222,000	180,000
*Irrigation date**	17 Sept.	19 Sept.	14 Sept.
Pre-irrigation	Yes	No	Yes
*Treatments***	**Growers (G):** Chlorpyrifos at planting plus post emergence sprays using chlorpyrifos/diazinon mixtures **(C/D)**	**Growers**: Chlorpyrifos at planting plus post emergence sprays	**Growers:** Chlorpyrifos at planting plus post emergence sprays
	Imidicloprid@45 g a.i. per 100,000 seeds **(I45)**	**Imidicloprid@45 g**	**Imidicloprid@45 g**
	Bt (Bacillus thuringiensis) 4 aerial applications	**Imidicloprid@45 g** + one post-emergence spray at 10 to 14 days: **(I45+)**	**Imidicloprid@45 g** + one post-emergence spray at 10 to 14 days
	Control + one post-emergence spray at 10 to 14 days	**Imidicloprid@20 g (I20)**	**Imidicloprid@20 g**
	Control (C): no pre- or post-emergence insect control	**Control**: no pre- or post-emergence insect control	**Control**: no pre- or post-emergence insect control
*# of post-emergence sprays applied to **Growers'** treatment*	**4**	**3**	**2**

*Fields were furrow irrigated twice before and during emergence, using alternate furrows. **All seeds were treated with metalaxyl and thiram (tetramethylthiuram disulfide) before planting.

Table 2. Results (Percent of seed sown)

Treatments	Cum. Emergence	Post emergence mortality	Pre-emergence mortality*	Establishment
		1999-2000		
Grower's	82.3	2.7	17.8	79.3
I45	79.4	5.1	20.6	74.1
Bt	55.6	5.5	44.4	49.7
Control	56.3	8.1	43.7	47.5
Control +	58.2	6.2	41.2	51.5
		2000-2001		
Grower's	50.9	6.8	49.2	44.1
I45	40.0	9.6	60.0	30.0
I45 +	40.1	5.8	59.9	32.6
I20	39.6	5.8	60.4	34.3
Control	34.0	9.7	66.0	24.3
		2001-2002		
Grower's	68.3	1.3	31.7	67.0
I45	64.4	1.9	35.6	62.5
I45 +	66.8	0.8	31.2	66.1
I20	67.9	2.5	32.1	66.4
Control	51.7	0.7	48.3	51.0

* Includes non-viable seed and planter skips.

Table 3. Single degree of freedom contrasts for emergence and mortality. F tests and probability of F.

Treatment Comparison	Cumulative Emergence		Post emergence mortality		Total established	
	F	*p* =	F	*p* =	F	*p* =
			1999-2000			
Growers vs control	50.41	<0.0001	34.85	<0.0001	69.26	<0.0001
Imidicloprid vs control	40.35	<0.0001	10.63	0.0016	48.40	<0.0001
Growers vs Imidicloprid	0.56	0.4556	6.84	0.0106	0.88	0.3948
			2000-2001			
Growers vs control	68.28	<0.0001	4.60	0.0348	74.26	<0.0001
Imidicloprid vs. control	8.62	0.0043	2.25	0.1372	41.26	<0.0001
Growers vs. Imidicloprid	39.4	<0.0001	0.02	0.9018	6.23	0.0145
I45 vs. I20	0.05	0.8284	5.56	0.0207	2.33	0.1310
			2001-2002			
Growers vs. control	21.65	<0.0001	0.74	0.3919	19.31	<0.0001
Imidicloprid vs. control	9.26	0.0031	1.77	0.1872	7.53	0.0074
Growers vs. Imidicloprid	2.97	0.0886	0.37	0.5456	2.49	0.1182
I45 vs. I20	1.32	0.2535	0.15	0.6967	1.41	0.2384

Table 4. Single degree of freedom contrasts for yield. F tests and probability of F.

Treatment Comparison	Root yield		Sugar %		Gross sugar yield	
	F	*p* =	F	*p* =	F	*p* =
			1999-2000			
Growers vs. control	23.56	0.0093	10.22	0.127	6.81	0.0311
Imidicloprid vs. control	10.37	0.0537	0.65	0.4425	4.03	0.0797
Growers vs. Imidicloprid	1.32	0.2866	5.71	0.0439	0.36	0.5628
			2000-2001			
Growers vs. control	1.55	0.2497	0.00	0.9898	2.34	0.1647
Imidicloprid vs. control	0.25	0.6172	1.23	0.2988	1.32	0.2843
Growers vs. Imidicloprid	0.74	0.4139	2.51	0.1515	0.09	0.7748
I45 vs. I20	0.000	0.9814	0.00	0.9848	0.00	0.9614
			2001-2002			
Growers vs. control	2.40	0.1599	0.39	0.5484	3.37	0.1038
Imidicloprid vs. control	3.00	0.1217	1.22	0.310	1.97	0.1985
Growers vs. Imidicloprid	0.00	0.9467	3.27	0.1080	0.53	0.4866
I45 vs. I20	0.04	0.8417	0.09	0.7695	0.02	0.9002

Table 5. Variable costs of stand establishment ($/ha)

1999-2000		2000-2001		2001-2002	
Growers[1]	181.45	Growers	158.40	Growers	130.12
I45[2]	178.84	I45	107.16	I45	77.78
Bt	225.38	I45+[3]	149.50	I45+[3]	121.00
Control +[3]	39.11	I20[2]	47.65	I20	34.57
Control	0	Control	0	Control	0

1. Grower's treatment involved chlorpyrofos at planting and up to 4 post-emergence aerial applications of chlorpyrifos/diazinon (see Table 1). Higher costs are related to larger numbers of treatments.

2. The cost of imidicloprid declined each year because the amount of seed used declined (Table 1). The cost of imidicloprid application to an encrusted seed was estimated as $1.00 per g a.i.

3. Included one post emergence application of chlorpyrifos/diazinon at approximately 14 to 16 days post emergence.

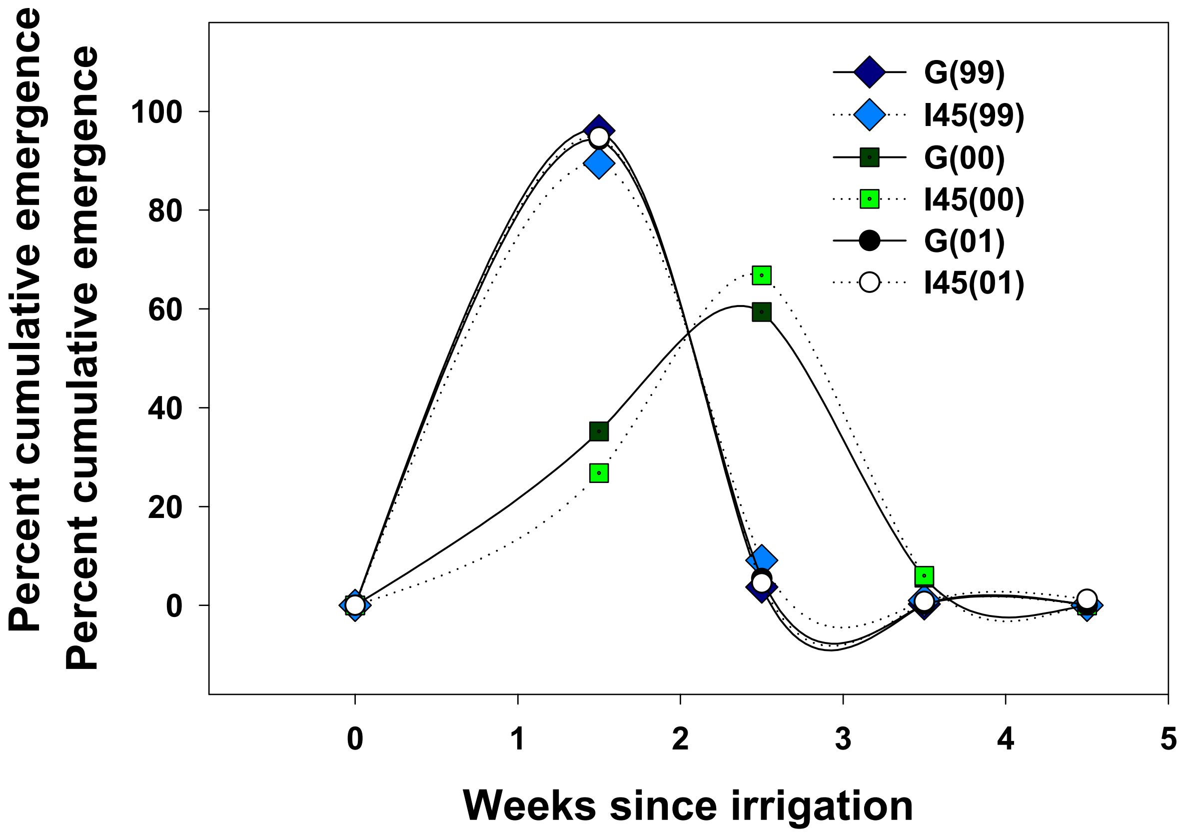


Fig. 1. Percent cumulative emergence for selected treatments in all three years. G99: Growers treatment in fall 1999, G00: Growers treatment in fall 2000, G01: growers treatment in fall 2001. I 45 (99) -(01): imidicloprid at 45 g a.i. per unit of seed in fall 1999 through fall 2001 (See Table 1 for symbols).

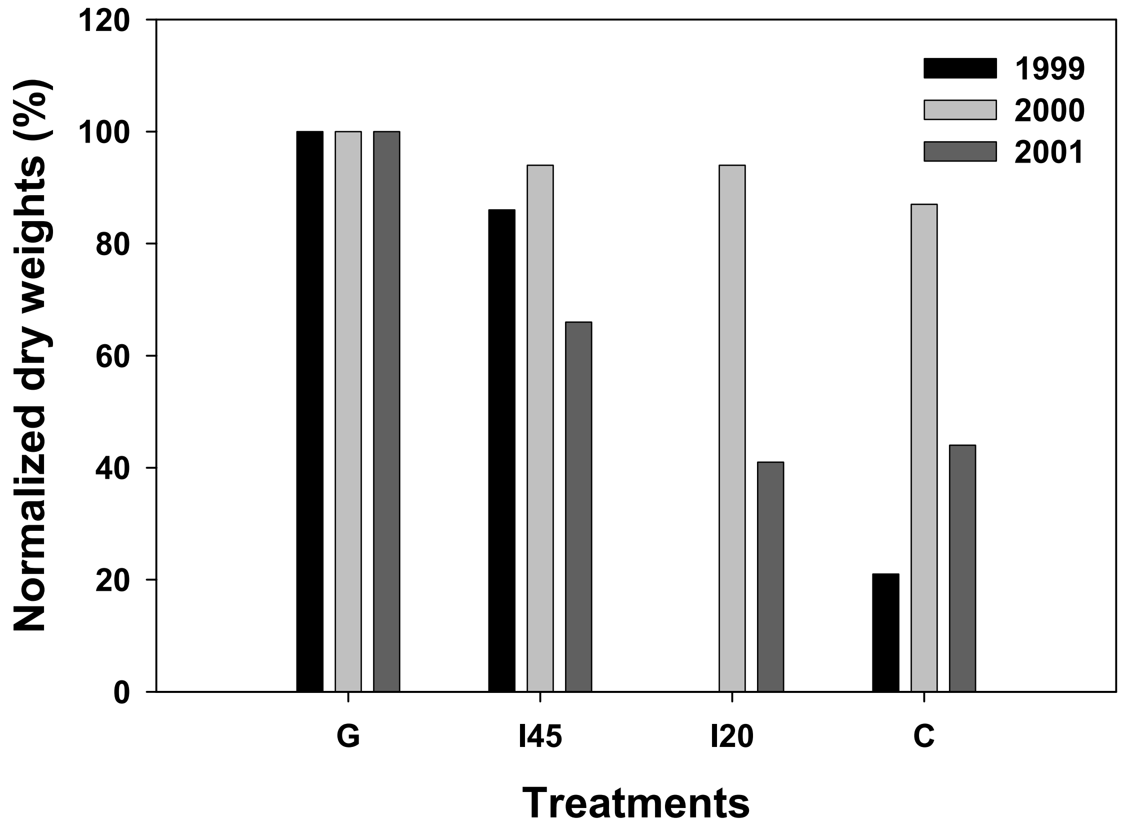


Fig. 2. Normalized seedling dry weights by treatment for all three experimental years.

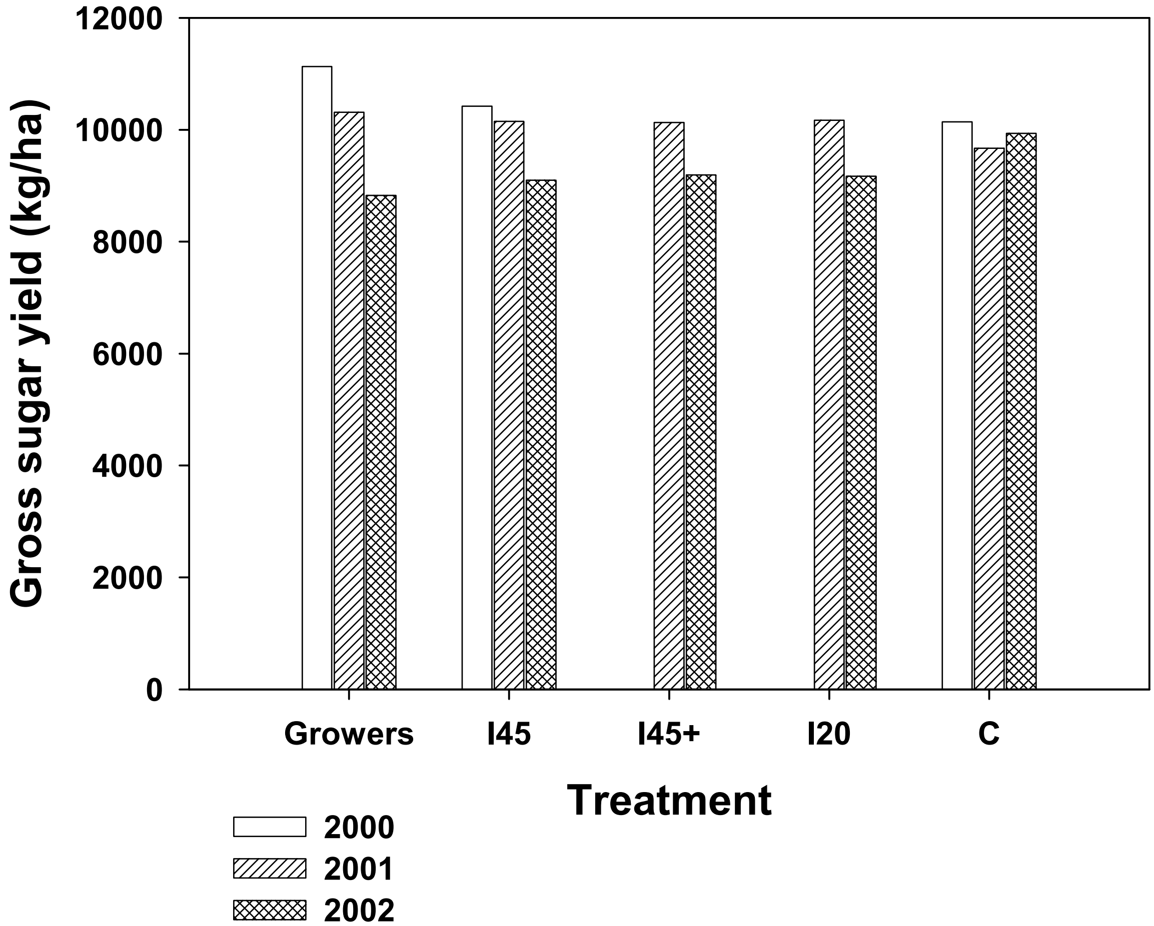


Fig. 3. Gross sugar yield (kg ha^{-1}) in all three years. For significant differences see Table 4.

Reduced Risk Management of Insect Pests in Sugarbeet

Final Report

Objective 2: Demonstration of Reduced Risk Management of Sugarbeet Armyworm: L. Godfrey

Rationale

Sugarbeet production in California is hindered by several insect pests. These pests cause significant yield losses and also increase costs of production. In 2001, ~ 50,000 acres of sugarbeets were planted in California; the production was concentrated in the central/southern San Joaquin Valley and in the Imperial Valley. Sugarbeets are important contributors to the agricultural economies in these areas with a farm gate value estimated at $60,828,000 and the value of sugar and by-products from this crop estimated at $142,625,000. In the San Joaquin Valley, sugarbeets are an important rotational crop and are well suited for the moderately saline soils common in the area. In the Imperial Valley, sugarbeets fill a niche for a "winter" crop and are ideally adapted for these environmental conditions.

The beet armyworm (*Spodoptera exigua*) is a significant pest of sugarbeets in California and improved management of beet armyworms has been identified by the industry as a priority area because insecticide treatments for control of sugarbeet armyworm (BAW) are expensive, not consistently efficacious, and contribute to secondary pest outbreaks, such as spider mites and leafhoppers. Current BAW control practices rely on organophosphate and carbamate insecticides, which are under scrutiny from several viewpoints including the Food Quality Protection Act, health risks to workers, and environmental concerns primarily contamination of surface waters. Sugarbeet growers need viable alternatives to current practices that are sustainable and less likely to cause secondary pest problems.

To facilitate adoption to "reduced risk" practices by California growers, the Department of Pesticide Regulation enacted a Pest Management Alliance Program in the late 1990's. This program stressed forming a coalition representing all aspects of an industry including growers, consultants, commodity board, processors, research and extension to discuss viable management alternatives and to plan means to facilitate implementation of these practices. Appropriate demonstration studies of these practices was one of the cornerstones of this program.

Introduction

Beet armyworm (*Spodoptera exigua*) larvae remain a significant insect pest of sugarbeets in the Central Valley. The variety of crops in the central San Joaquin Valley and in the Imperial Valley, the primary areas of sugarbeet production, facilitate the build-up of beet armyworm (BAW) populations. This pest has a wide host range with important crop plants of cotton, beans, melons, tomatoes, lettuce, alfalfa, potatoes, being damaged in addition to sugarbeets. The related species, western yellow-striped armyworm, *Spodoptera praefica* , occurs in conjunction with BAW in many cases. Beet armyworm eggs are deposited in clusters of ~100 on the leaf surface. Egg masses are covered with hairlike scales. Newly-emerged larvae feed in a cluster initially and than move over the plant. The larvae skeletonize plant leaves leaving the veins. Western yellow-striped armyworms inflict similar damage to crop plants although the biology of this species differs in several cases. On sugarbeets, defoliation of leaves can cause significant yield losses; however, a mature sugarbeet plant can “sacrifice” significant leaf tissue without substantial yield loss. However, in many cases, plants are entirely defoliated by the larval feeding which, of course, is problematic. In addition, in recent years, BAW larvae are feeding in more protected areas of the plant than populations in the 1970's and 80's. This has resulted in the larvae often feeding on the beet roots near the soil surface or slightly below the soil surface (larvae crawl into soil cracks caused by the roots) and in the crown of the plant instead of on the exposed leaves. This root feeding provides entry ports for root rotting organisms into the beet roots. These root rot diseases can quickly decimate a sugarbeet stand or nearly mature crop. Finally, beet armyworm larvae also inhibit sugarbeet seedling establishment by clipping emerging seedlings; this can result in inadequate stands and the need for replanting.

Control of beet armyworm infestations during the growing season over the last ~15 years has been largely accomplished with applications of organophosphate and carbamate insecticides (primarily Lorsban® and Lannate®). Insecticide usage in these two classes has comprised up to 90% of the applications in sugarbeets. The use of biological insecticides, although never very high, reached a peak of 7.4% of the applications (1996) but in recent years has declined. Pyrethroid usage was 9.4% of the applications in 2000; the pest spectrum in sugarbeet limits the utility of pyrethroid insecticides. In addition, SJV growers are hesitant to use pyrethroids because of the potential for flaring spider mite populations in sugarbeets; there are no miticides registered in sugarbeets. The availability of Success® for use in sugarbeets has been an advantage in terms of BAW control. This product is quite costly, however, and this further strains the economics of sugarbeet production. In addition, Success® does not adequately control western yellow-striped armyworm.

In recent years in the Central Valley, repeat applications of insecticides are often needed for acceptable BAW control and control has still been inadequate. These applications have eroded the profitability of sugarbeets and the lack of control has reduced the sucrose yields. In addition, the multiple applications have flared populations of secondary pests such as spider mites, leafhoppers, etc. In 2000, Alliance fields were heavily damaged by spider mites and *empoasca* leafhoppers. Regardless of the treatment, the beets were nearly completely defoliated by about 1 month before harvest. When this occurs, the plants regrow, utilizing stored sucrose that could go into sucrose at harvest, further compromising yield. In 2001 Alliance demonstration fields, pheromone traps appeared to foretell the timing of larval infestations and were useful for determining the timing of treatment. Based on plant damage and beet yields, the biorational approach was equal to or better than the conventional treatment. However, the BAW pressure and spider mite levels were usually low in 2001. This contrasts with 2000 when neither strategy provided acceptable management of beet armyworm and/or the secondary pest complex.

Materials and Methods
Work for this objective was conducted in Fresno County

Tasks 1 and 3

Reduced risk management of beet armyworm (*Spodoptera exigua*) larvae was demonstrated in commercial sugarbeet fields in Fresno County. This project fulfilled objective 1 of the Pest Management Alliance project 'Reduced Risk Management of Insect Pests in Sugarbeets'. Two late fall/winter planted fields were utilized in which the biorational practices were used on 30 acres compared with the standard practices on the remaining ~60 acres. The PCA was involved in making decisions on the grower-practice side and we, in concert with the PCA, made management decisions on the biorational side. Management of BAW through biorational means consisted of:

1) tolerating slightly more defoliation damage than normal,
2) monitoring BAW moth flight with pheromone traps, and
3) monitoring in-field populations of BAW eggs and larvae. The control tactic for the biorational treatment was to use B.t. sprays at the onset of egg hatch. This would concentrate the activity of B.t. onto the early instars, where it is most effective. The grower practice was to use "as-needed" applications of Lannate®, Lorsban, or other organophosphate insecticides or of Success®.

The following samples were collected on a weekly interval from late May through September:

1) bucket pheromone traps baited with BAW pheromone were placed in each field on 23 May,
2) sweep net samples were taken weekly in each field (grower and biorational portions), samples were taken to the laboratory and the numbers of beet armyworm larvae, Empoasca leafhoppers, and beneficials (lygus bugs, stink bugs, minute pirate bugs, big-eyed bugs, assassin bugs, damsel bugs, lacewings, lady beetles, collops beetle, parasitic wasps, and spiders) were counted,
3) visual inspections were done on 20 leaf samples weekly in each field/treatment to assess the numbers of beet armyworm egg masses and larvae,
4) leaf samples (20 per field/treatment) for spider mites were collected in August and Sept. as populations developed to noticeable levels; samples were processed in the laboratory with a washing technique,
5) defoliation ratings were made weekly on a 1-10 scale with 1 being no defoliation and 10 being complete defoliation,
6) harvest samples (from a commercial harvest) were collected in October from both fields and from the biorational side and the grower standard side; about 10 acres was harvested from each "plot",
7) sucrose content was determined at the Spreckels tare laboratory and sucrose yields were calculated.

Results

Tasks 1 and 3

Pheromone traps: Beet armyworm moths were detected in significant numbers in the initial sample and for the rest of the season. More moths were captured in Field 2-52 than Field 10-7 until mid-July and after that date the inverse was true (fields were about 1 mile apart). Peak moth flights occurred in mid June, early July, and early-mid Aug (Fig. 1). These flight peaks were about 2-3 weeks earlier than in 2000 and 2001 (Fig. 2); traps were within ~7 miles of the 2000 and 2001 locations. Therefore, it is important to monitor moth flights annually rather than to use "calendar date". However, the numbers of BAW moths captured in 2002 was less than in the previous 2 years.

Research in cotton has shown that ~930 degree-days (882 for females and 977.9 for males) (54 F lower threshold) are needed for development of BAW from egg to adult. The developmental rate on sugarbeets is unknown (developmental rates can vary significantly among hosts). Using 20 May as the estimated initial date of oviposition, i.e., when the moths forming flight peak 1 started to fly, the second flight peak should start about 3 July. The pheromone trap data generally agreed with this prediction. The next generation adults should appear on 10 Aug based on degree-day accumulation. Again the moth captures in traps corresponds with this prediction. However, the trap captures showed an increase in numbers starting in early August (actually numbers never approach zero between the second and third flight peaks). Therefore, the degree-day accumulation accurately predicted the timing of the second flight peak as well as the third flight peak.

Table 1. Field Treatments: The following treatments were applied to these two fields for beet armyworm management.

Field	Date	Biorational Approach	Grower Approach
2-52	13 July	none	Success®
10-7	30 July	Xentari®	Dibrom® + Lannate®

Xentari® was used for the Bt treatment in this project. Lepinox® had been used successfully in 2001; however, FMC has given up this product from their portfolio. Certis has acquired the product but it was not commercially available yet.

Beet Armyworm Populations: BAW larval populations from each of the two fields are shown in Fig. 3 (sweep samples) and 4 (leaf samples). Larval populations were low until early July; at this time, populations increased until mid-August. Populations peaked in early August. Moth flights were still high at this time, but the irrigation was stopped on the fields at this time in preparation for harvest. This made the leaves not conducive to larval infestation. In addition, a viral disease greatly reduced larval populations in August. This was the second year this has been observed. BAW larval levels were about 2x higher in field 10-7 compared with field 2-52. This is one reason why the biorational side of Field 2-52 was never treated whereas Field 10-7 was treated. The Success® treatment (grower approach) in Field 2-52 was effective in reducing an already low population of BAW larvae. Populations in Field 10-7 declined following the insecticide applications on 30 July; however, levels declined also in Field 2-52 at this time. As we observed in 2001, a virus disease decimated larval populations near the time of peak populations. This was particularly evident in 2002. Overall, worm levels were somewhat higher under the grower approach compared with the biorational approach.

Beneficials: Numbers of beneficial insects were generally greater in the portion of the field under the biorational approach compared with the conventional approach; however differences were not large (Fig. 5). There were two peaks in numbers of mid-June and ~10 August and numbers reached about 0.5 per sweep. Beneficial levels were somewhat higher in Field 2-52 than Field 10-7.

Spider Mites: Spider mite levels were overall significant in 2002 (Fig. 6). Mite infestations did not appear until mid-July. Populations peaked at nearly 100% infested leaves on 8 August and 14 August in Field 2-52. Levels were about one-half that in Field 10-7. Populations did not differ greatly between the two management approaches, but tended to be slightly higher in the biorational approach.

Leafhoppers: Leafhopper populations built-up to significant levels, especially in Field 2-52 (Fig. 7). Populations were virtually nonexistent until ~10 July. Levels then increased consistently and peaked at about 450 per 50 sweeps. Populations were higher in Field 2-52 than Field 10-7 and in the biorational approach compared with the grower approach.

Yields: Yields were overall higher in 2002 than in 2000 and 2001. The biorational approach produced higher yields in both fields (table 2). Overall, this management strategy produced about 22% more sucrose yield.

Table 2. Yield results from PMA sugarbeet project, Fresno County, 2002.

Field	Treatment	% Sugar	Sugar/A (t)
10-7	Biorational	14.16	6.2
10-7	Conventional	12.58	3.8
2-52	Biorational	15.34	7.4
2-52	Conventional	15.11	6.7

Discussion

For this Fresno County study, pheromone trap catches and degree-day accumulations were generally in agreement. The armyworm flight had three peaks (generations) and the second and third generations were high. The bucket traps seemed to foretell the timing of larval infestations and were useful for determining the timing of treatment. Use of the wing traps was discontinued in 2001. Based on plant damage and beet yields, the biorational approach was equal to or better than the conventional treatment. Populations of secondary pests, spider mites and leafhoppers, were similar under both approaches.

Summary and Conclusions

The use of pheromone traps with degree day accumulations showed promise for beet armyworm. More effective reduced risk materials would aid this management program. Ideally, these materials would provide effective pest control and conserve populations of natural enemies which would reduce the build-up of secondary pests such as spider mites. A more refined treatment threshold would also be helpful. This would allow growers to concentrate treatments when they are most critically needed. This is important given the elevated costs of most of the reduced risk materials and this information would facilitate adoption. Otherwise, “blanket” treatments of cheaper, traditional materials may continue to be the favored strategy.

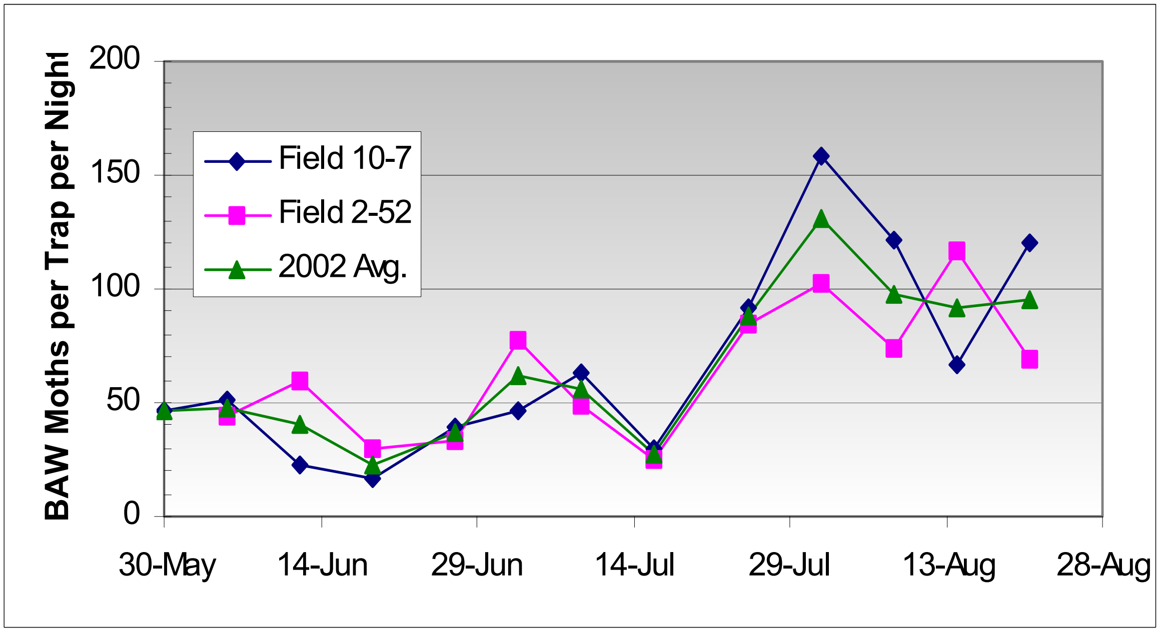


Figure 1. Beet Armyworm moth flights from pheromone traps located near sugarbeet fields in Fresno County, 2002.

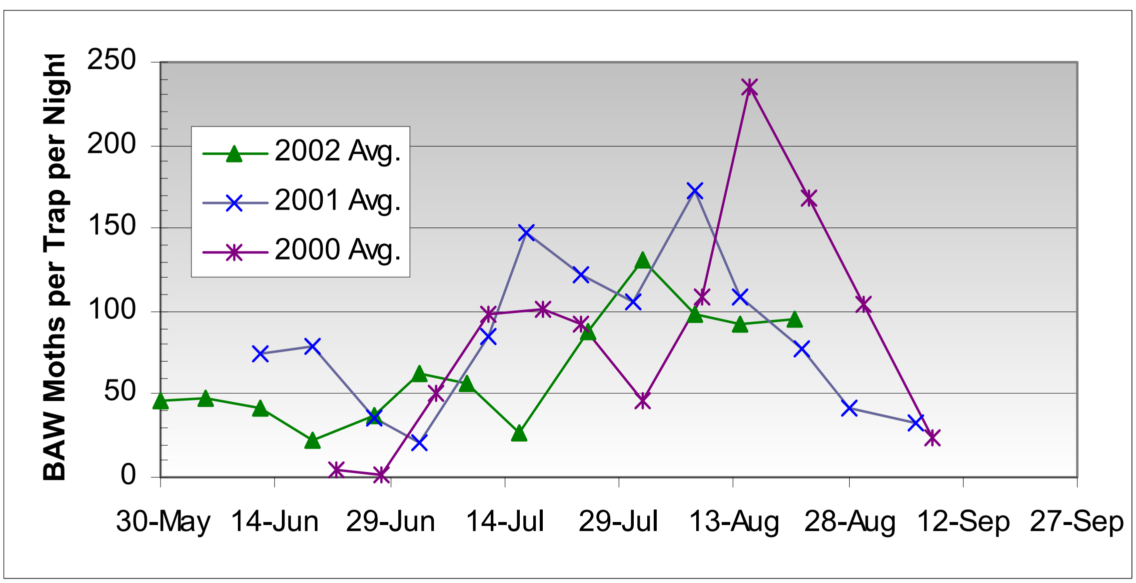


Figure 2. Comparison of Beet Armyworm moth flights from pheromone traps located near sugarbeet fields, Fresno County, 2000, 2001, and 2002.

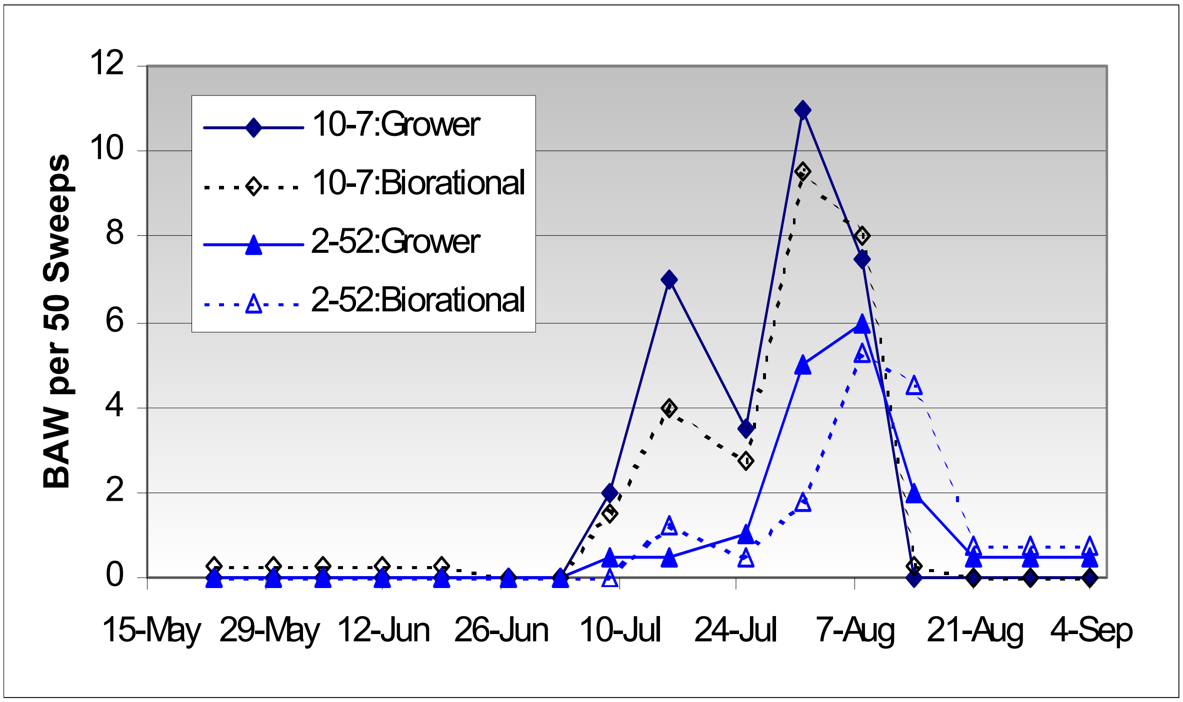


Figure 3. Beet Armyworm larval populations from sweep samples in sugarbeets under two management regimes, Fresno County, 2002.

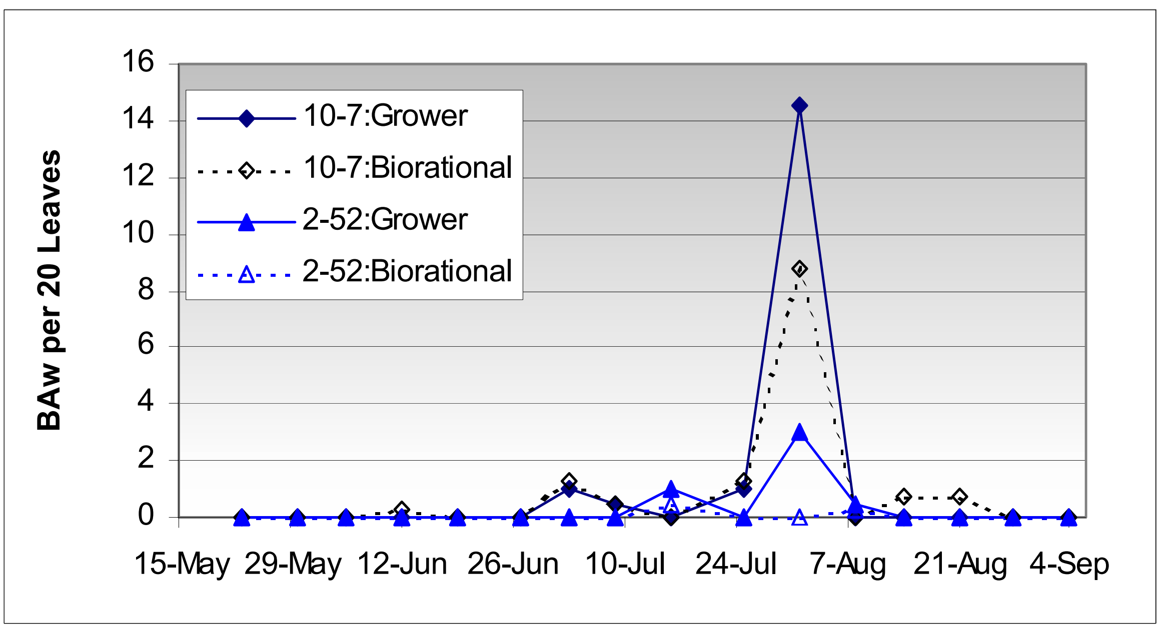


Figure 4. Beet Armyworm larval populations from leaf-turn samples in sugarbeets under two management regimes, Fresno County, 2002.

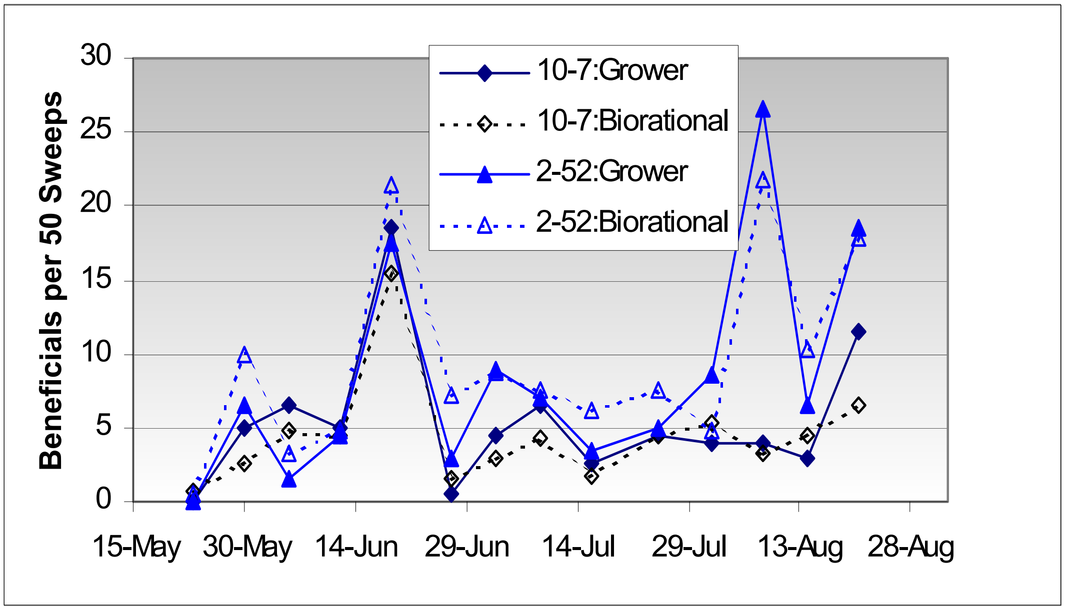


Figure 5. Populations of beneficials in sugarbeet fields under two management approaches for Beet Armyworm, Fresno County, 2002.

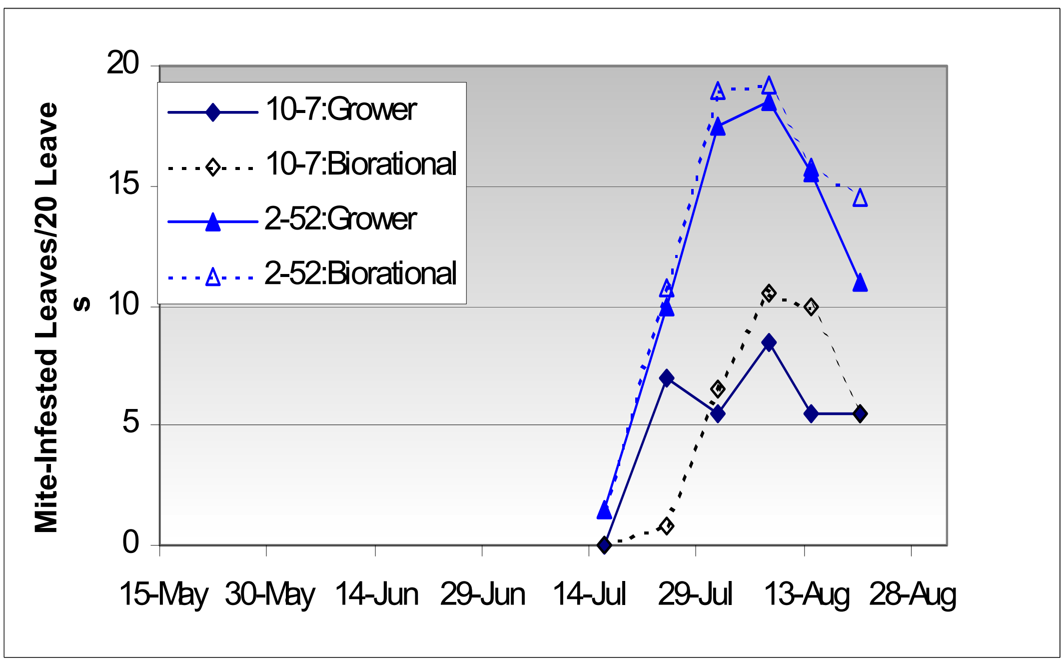


Figure 6. Influence of two management approaches for Beet Armyworm in sugarbeets on levels of spider mites, Fresno County, 2002.

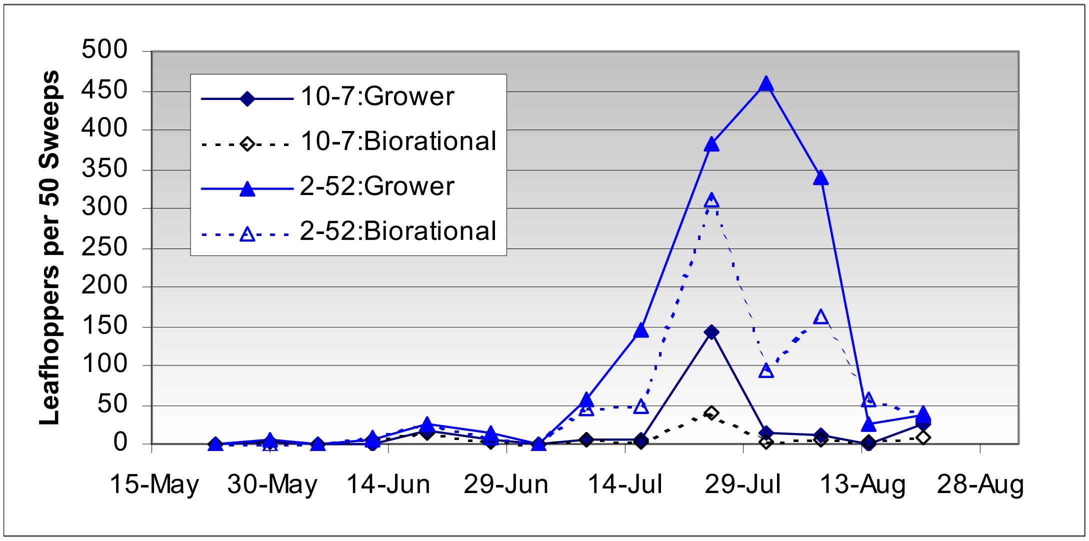


Figure 7. Influence of two management approaches for Beet Armyworm in sugarbeets on levels of leafhoppers, Fresno County, 2002.

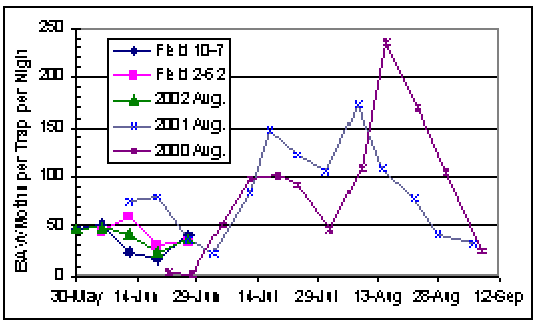
List of Publications Produced

Results were summarized and faxed to industry and grower cooperator personnel on a weekly basis. An Example of one such report is shown below.

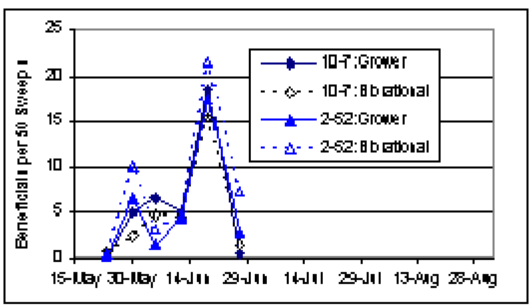
Summary of Pest Management Alliance Sugarbeet Fi

through week of June 23 2002

Larry Godfrey, UC-Davis Entomology, 530-752-0473 (o),



Beet armyworm moth f
fields 10-7 and 2-52 is
compared with the fligh
2001. For the week of
armyworm moth flight
previous week. This li
moth flight is starting b
it will be ~2 weeks bef



Populations of benefic
compared with the pre
"crash" in beneficial n
during late June. This
in mid-July. The reas
but three theories are
fields due to the lack c
hot temperatures make
sample with the sweep
killed by applications
mildew. Lady beetle
predator on 27 June 2

Leafhopper populations were also much lower this week than last week. No beet armyworm larvae were found in these fields in sweep net samples and in leaf turns. A few beet webworm larvae were found in Field 10-7 and in other fields in the area that I examined. These larvae can also defoliate sugarbeets but the damage potential and actual damage done are generally less than for beet armyworms. Beet webworms differ from beet armyworms by 1.) feeding more in the plant growing point, 2.) feeding in a webbed area comprised of a rolled-up piece of leaf, 3.) feeding

Several oral presentations have been made on this project. Results were discussed at the UC Sugar Beet Workgroup meeting. Results were presented to the District 6 Sugar Beet Growers (Fresno County) at their annual meeting in November 2002. To the scientific audience, a presentation was made at the Entomological Society of America meeting and two poster presentations from this project were made at the American Society of Sugar Beet Technologists meeting Feb. 2003.

Acknowledgments

We thank the California Dept of Pesticide Regulation for funding this demonstration/Alliance project. In addition, the assistance of Richard Heimforth, the Spreckels Sugar Co., Kevin Keillor, David Haviland and the grower/PCA cooperators was greatly appreciated.

APPENDIX A:

ARTICLES AND PRESENTATIONS FROM PMA PROJECT

Godfrey, L. D. Sugarbeet PMA results from Fresno County work. Presented to District No. 6, California Beet Growers, November 7, 2002.

Haviland, D.R., **Godfrey, L.D.**, and K. Keillor. The development of an IPM strategy for beet armyworm (*Spodoptera exigua*) in California sugarbeet. Presented to Entomological Society of America. November 19, 2003, Ft. Lauderdale, FL.

Haviland, D. and **Godfrey, L. D.** Beet armyworm management in sugarbeets. Presented to Annual Sugarbeet Research Review. January 17, 2003.

Godfrey, L. D., D. Haviland, and B. Goodwin. Progress toward implementing reduced risk management of beet armyworm (*Spodoptera exigua*) in California sugarbeets. Presented to American Society of Sugarbeet Technologists. March 1, 2003, San Antonio, Texas.

Haviland, D. R., **Godfrey, L. D.**, and K. Keillor. The development of IPM for beet armyworm (*Spotoptera exigua*) in California sugarbeets. Presented to American Society of Sugarbeet Technologists. March 1, 2003, San Antonio, Texas.

Kaffka S. R. (submitted). Seed treatments can be used to reduce stand establishment losses in the Imperial Valley. J. of Sugar Beet Research

Kaffka, S.R.,. (2003). Improving stand establishment while reducing pesticide use in California's Imperial Valley. Pg 285-294 In: Proceedings of the 65th IIRB Congress, Feb. 2002, Brussels, Belgium

Kaffka, S.R., and Babb, T. (2003). Insecticide use during stand establishment in the Imperial Valley can be reduced. Pg 559-566. In: Anon. 1st Joint IIRB-ASSBT Congress, San Antonio, Texas, USA. International Institute of Sugar Beet Research, Brussels, Belgium, 956p

Kaffka, S.R. and Babb, T. (2003). Seedling IPM in the Imperial Valley. Pg 56-62 In: Proceedings, California Plant and Soil Conference, Feb. 5 and 6, Modesto, CA.

Kaffka,S.R. (2002). New best management practices for sugar beet stand establishment in the Imperial Valley pg 14-15, 27-28. *The California Sugar Beet*. California Beet Growers Association, Stockton, California.

Kaffka, S.R. (2001). Alternatives to current stand establishment practices in the Imperial Valley look promising . *The California Sugar Beet*, California Beet Growers Association, Stockton, California

Kaffka, S.R., and Babb, T. (2001). Pre-emergence insecticides improve seedling emergence in the Imperial Valley. Amer. Soc. Sugar Beet Technologists. Proc. From the 31st Biennial mtg. Vancouver B.C. Pg 137-142.

Kaffka, S.R.: Alternative Practices for stand establishment in the Imperial Valley. Presented August 28, 2003, Imperial Valley PCA meeting.

Kaffka, S.R. and T. Babb: Stand establishment in the Imperial Valley. Presented to American Society of Sugarbeet Technologists. Feb. 26, 2003, San Antonio, Texas.

Kaffka, S.R. and T. Babb: New /PM practices for sugarbeets in the Imperial Valley. Presented to the California Chapter of American Society of Agronomists. February 5, 2003, Fresno, California.

Kaffka, S.R.: Current results from stand establishment in the Imperial Valley. Presented to Annual Sugarbeet Research Review. January 17, 2003.

Kaffka, S.R.: Project poster presentation on New stand establishment practices in the Imperial Valley to the International Institute of Sugarbeet Research.. February 12, 2002. Brussels, Belgium.

Kaffka, S.R.: Presentation of current results from stand establishment in the Imperial Valley to the Annual Research Review for Sugarbeets. January 28, 2002. Davis, California.